Selections from the history of environmental pollution, with special attention to air pollution. Part 2*: From medieval times to the 19th century

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Abstract: Several comprehensive publications have been issued recently on the environmental pollution of past times, especially from medieval times (e.g. Brimblecombe, 1987a; Goldstein, 1988; Brimblecombe and Pfister, 1990; Hughes, 1993; Markham, 1994; Brimblecombe, 1995). The aim of this paper is to give an overview of information on the subject – mainly related to the period between medieval times and the 19th century.

Keywords: air quality, control of air pollution, effect of pollutants, fog in literature and the fine arts, London Great Smog, smoke inspection.

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Biographical notes

Peter Brimblecombe is Professor in Atmospheric Chemistry at the School of Environmental Sciences, University of East Anglia. He did a PhD on the aqueous chemistry of sulfur dioxide in the atmosphere at the university in Auckland, New Zealand. He maintains an interest in atmospheric sulfur chemistry, and currently is chiefly concerned with the thermodynamics of the concentrated aqueous aerosol and its effects in the chemistry of polar stratospheric cloud droplets that play a role in ozone depletion. He continues to be interested in long-term changes in urban air pollution and its effects on health and buildings. The historical aspects of this work formed the subject of a book, *The Big Smoke*. His interest in material damage by air pollutants has not been restricted to outdoor environments: he has done some work on the

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museum atmosphere and has a continuing interest in the process of damage to cultural materials by air pollutants. He has written on the history of acid rain, early air pollution in Manchester, and the influence that urban air pollution had on architecture in late Victorian England. He was appointed senior editor of *Atmospheric Environment* in 1990.

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1 Air pollution in medieval towns

Before the age of modern industrialization, only the pollution of air was mentioned in various sources; however, no air samples were analysed. In Arles and Bologna, soil layers were examined from the periods 1180–1636 and 1530–1887, respectively. In the samples from both cities, large quantities of ash, an end-product of wood burning, were detected. This suggests the presence of polluted air caused by wood burning in the cities of Southern France and Northern Italy from the medieval ages till the beginning of the industrial revolution (Ausset *et al.*, 1998).

In early societies, wood burning and heating played a key role in the development of air pollution, which was then mainly restricted to the pollution of inner spaces. The early cities were established in small areas; on the other hand, their population densities were high. This dense inhabitation provided a better means for defence and the facilitation of movement of people and transportation of goods within the limits of the cities. Under such circumstances, when descending air currents were experienced, smoke from forges, breweries and other manufacturing facilities requiring energy, accumulated among the houses. Medieval cities in Europe were generally characterized by high buildings. The streets between densely populated houses might have formed a canyon, which probably retained smoke and vapour.

1.1 Air quality in medieval Manchester

Throughout the medieval period, Manchester was a wealthy manufacturing and merchant town, a provincial capital and focus for commerce. In the early 16th century it was described as the 'fairest, quickest and most populous town' of Lancashire (Toulmin Smith, 1964). Nuisance complaints were 'presented' to the local court and the defendant was usually fined and requested to abate the nuisance.

Between 1801 and 1841 the population of Manchester increased from 70 000 to 243 000 as a result of the massive immigration of workers. The urban conditions were

appalling. In 1843 a petition published in the *Manchester Guardian* estimated that there were 500 industrial chimneys in the town, and a report of 1859 identified 31 of these as being particularly offensive. These included oil-cloth works, artificial manure works, alum works, tanneries, potteries and turpentine works (Bowler and Brimblecombe, 2000a).

The effect on Manchester's atmosphere was dramatic. Alexis de Tocqueville described in 1835 how 'a dense smoke covers the city. The sun appears through it like a disc without rays' (Lawrence and Mayer, 1958).

1.2 Attempts in Manchester to control air pollution

The Manchester Court Leet jury employed nuisance law in 1592, when it ordered an inhabitant to construct his chimney so that it 'be not noysome to his neighbour' (Thomson, 1967). Throughout the early 1700s, Manchester Court Leet also dealt with several public complaints of illicit firing of sooty chimneys as a public nuisance, and ordered the imposition of fines for subsequent chimney fires. In 1785, the Court perceived the tobacco pipe maker's works in Todd Lane was a nuisance and this was ordered to be removed. In such cases the damage caused by these nuisances was the unacceptable fouling of a neighbour's air. Here too the nuisance law insisted that certain trades, even though they were lawful and necessary, could be closed and forced to move if they were nuisances. This resulted in the zoning of offensive trades to certain areas (Bowler and Brimblecombe, 2000a).

By the end of the 18th century, the uninhibited expansion of steam-powered factories resulted in a prolific growth in the number of chimneys and the amount of smoke emitted. In 1801, the Manchester Court Leet prosecuted 11 cotton-spinning factory owners for burning large quantities of coal, which 'unlawfully' and 'injuriously' made 'great quantities of smoke and soot' to issue onto adjacent houses and into the streets and common highways 'to the great damage and common nuisance of the inhabitants of the Manor' (Earwaker, 1884–1890).

The threat of prosecution was acknowledged by contemporary industrialists and caused some interruption to their business endeavours. In 1790, the cotton mill owned by the Manchester textile entrepreneur Peter Drinkwater became operational. A year later, James Watt noted that 'Mr. Drinkwater at Manchester was threatened per advance with a prosecution if he made any smoke; he has, however, taken care not to do so, and has escaped hitherto' (Chaloner, 1954).

In 1800, a 'Nuisance Committee' was appointed 'to attend to, and report to the General Commissioners all nuisances in Manchester'. The Nuisance Committee believed that chimneys should be constructed to consume their own smoke, but did not set out specific measures through which to achieve this aim. From 1808, smoky chimneys were being dealt with by the Nuisance Committee, and standardized administrative procedures for their control were developed. Constables appointed by the local 'Police Commissioners' took on the role of public health officers. They were required to act as 'Inspectors of Nuisance', the role of whom was primarily to aid the Medical Officer of Health. The 1835 Municipal Corporation Reform Act facilitated the comparative analysis of local administrative responses to air pollution during the Victorian era. The increasing number of Public Health Acts passed during the second half of the 19th century also provided improved powers to local authorities to control smoke. In 1844, a new Nuisance

Committee, appointed by the local Council, advertised in Manchester newspapers and distributed notices stating that proceedings would be instituted against all parties 'who offend and neglect to consume smoke arising from their respective furnaces'. An Officer of Health was appointed on the 1866 Sanitary Act, which granted local administrators enhanced powers to abate smoke nuisance. The 1875 Public Health Act (applied to all areas except London) defined nuisance and required local authorities to appoint sanitary officials who were empowered to enter and inspect premises and to enforce the statute. Throughout the 19th century, Manchester's officials generally believed that they were reducing the smoke nuisance. Nevertheless, here as elsewhere, only a small fraction of industries emitting black smoke were successfully prosecuted (Bowler and Brimblecombe, 2000a).

1.3 Air pollution in medieval London

In medieval London many of the small-scale industries must have required a source of heat: ovens for bakers, kilns for brickmakers and furnaces for metal-workers. Even so, the city's industrial requirement for fuel must have been smaller than its domestic needs, which in winter would be large. To find large-scale use of fuel in medieval times, it is necessary to look at industries concerned with the production of building materials: pottery, tile, glass, iron, steel and lime. Iron-making, like many other early industries, would probably have been situated in the forest near a source of wood and well away from urban populations likely to complain of pollution.

The quantities of lime produced were very large as lime was extremely important to medieval society, being used in mortar and for agricultural application. Lime was produced by heating limestone ($CaCO_3$) to a high temperature in a kiln. This drove off the carbon dioxide to produce lime (CaO). When mixed with water to form cement it was converted into slaked lime [$Ca(OH)_2$]. Traditionally, limestone was burnt with oak brushwood. In requisition orders, such as those issued by Henry III in the building operations at Westminster in 1235, oak brushwood was specified as the fuel. However, change was so rapid that only 11 years later we find that a similar requisition order specified a different fuel:

> 'To the Sheriffs of London, 23 July, 1264
>
> Contrabreve to purvey for the King in the City of London without delay and without fail a boat-load of sea-coal and four millstones for the King's mills in Windsor Castle and convey them thither by water for delivery to the constable of the castle.'

Sea-coal, or carbonem marus, seems to have been so called because it was brought by sea to coastal centres in England during the 13th century. It must have appeared in London by early that century, because by 1228 there was a street in London called Sacoles Lane (Sacoles ≈ Sea-coal). Its approximate location is still evident to the pedestrian in London today – both Old Seacoal Lane and Seacoal Lane are to be found near Ludgate Circus. Despite the difficulties in establishing the way in which Seacoal Lane came to be named, it does signify a very early beginning to the importation of coal into London.

The earliest documented air pollution incident in England occurred not in London but in Nottingham. It is interesting to consider this case and to note the earliest reactions towards the new fuel. In the 1250s, Henry III initiated repairs to Nottingham Castle. Repairs were probably under way when Queen Eleanor visited the castle late in the

summer of 1257. She found it so full of the stench of sea-coal smoke that she was forced to leave for Tutbury Castle to preserve her health. Similar fears permeate almost all medieval complaints about air pollution.

This is so marked that it is necessary to ask why the sulphurous smell resulting from coal burning suggested to the medieval mind that the fumes were unhealthy. Certainly, foul smells had been long related to unhealthy airs. The Greeks gave the name 'miasma' to the unhealthy odours that arose from swamps. We still use the word today, but to mean a poisonous or infectious atmosphere. There were medieval examples of the fear of marshes: (1) the site of Winchester Cathedral had to be moved because of the unhealthy and foul-smelling bog that had formed around it; (2) the River Fleet in London was so malodorous that the monks at White Friars claimed that some of their brethren had died from the stench. This type of popular perception of the origin of diseases may have allowed ready association between the smell of burning coal and the effects of air pollution on health (Brimblecombe, 1987a).

1.4 Air pollution in 19th century York

The air of Victorian York was not considered to be severely polluted. The 19th century visitors tended to perceive it as 'smoke free', although this was only true by comparison with the major industrial cities. There had been a few isolated incidents concerning smoke pollution dating back to the 16th century, but there was no systematic legislative action until the 1850s. Some cities, such as Manchester, adopted smoke control regulations of their own in the first part of the 19th century, but a formalized approach in York awaited the passage of the Health of Towns Act 1853, which allowed the appointment of a Sanitary Inspector (Brimblecome and Bowler, 1990).

It is often argued that Victorian society was anxious not to burden industry with pollution abatement regulations. However, it is clear that equating smoke with wealth was by no means universally accepted. In York, a 'Smoke Nuisance Petition' was addressed to the Lord Mayor by hundreds of residents in the 1850s. They asked the Council '...a due supervision and control in this matter, such as in other towns and cities has been found sufficient to remedy the smoke nuisance (Smoke – York City Archives)'. The importance of the Public Health Act of 1875 is particularly clear in York. The failure to cure York's smoke problem appears to derive more from a lack of appropriate technology than a lack of resolve on the part of the administration at the end of the 19th century (Brimblecombe and Bowler, 1990).

2 Early attempts in London to control air pollution

In medieval London the pollution from coal burning was regarded as such a serious matter that a commission was set up to investigate the problem in 1285. Before this, as the first trial to regulate air quality, use of powder coal was prohibited in 1273. In 1306, a proclamation banned the use of sea-coal, but further legal notices issued only two weeks later suggest that the proclamation had been largely ignored. It is popularly believed today that one of the early offenders against these air pollution laws was hung, tortured or decapitated in 1307, although none of the writers who make the suggestion gives any primary reference for the incident.

The importance of chimney height in the distribution of air pollution was a problem in medieval London. As early as 1377, there were legal battles that implied a minimum chimney height within the city, and ever since there have been concerns over chimneys. As we well know, air pollution is lessened in the immediate vicinity of the pollution source, but in parallel there is a general decline of air quality in the neighbouring region.

Richard III (reigned 1483–1485) strongly taxed the use of coal. Henry IV (reigned 1399–1413) established a coal committee. Later, in 1661, Charles II (reigned 1660–1685) also established a committee to examine smoke and control emission sources. The first scientific work on the field of air pollution was published by John Evelyn in the same year. The title of his book: 'Fumifugium' or 'The inconvenience of the Aer and the Smoak of London Dissipated'.

Although the courts and Parliament tried to control air pollution within medieval London, their influence was slight. This may be seen in the seasonal distribution of pollution incidents brought to the notice of the civic authorities. If we assume that the number of complaints about air pollution is related to the frequency of the pollution problems, we can postulate that pollution of London at this time was very much a summer problem. A seasonal distribution of this type demonstrates that the usage of coal was not for domestic heating, because use for heating would be expected to show a winter peak rather like that seen today.

Complaints found in 13th century documents point to the lime industry as being the main source of air pollution within medieval London. Such a conclusion would be consistent with the large amounts of coal burnt in lime production (thousands of tons) compared with only a ton or so used by a single forge in a year. Lime production in the 13th century culminated in the summer, because construction work took place during this season. The building work closed down for the winter, when shorter days and bad weather made outdoor construction difficult. Thus the seasonal distribution of lime production was parallel to that of complaints about air pollution mentioned before.

Not all the litigation over air pollution concerned the major sources. Quite ordinary people seemed to bring complaints before the authorities. They were quick to realize that pollution could affect property values. For instance, in the 14th century a case was brought before the London Assize of Nuisance:

> 'Thomas Yonge and Alice his wife complain ... the chimney is lower by 12 ft than it should be and the blows of the sledge-hammers when the great pieces of iron called 'Osmond' are being wrought into 'brestplates', 'quysers', 'jambers' and other pieces of armour, shake the stone and earthen party-walls of the house so that they are in danger of collapsing, and disturb the people and their servants day and night, and spoil the wine and ale in their cellar, and the stench of the smoke from the sea-coal used in the forge, penetrates their hall and chambers, so that whereas formerly they could let the premises for 10 marks [£6 13s 4d] a year, they are now worth only 40s.'

The defence offered by the armourers, in this case, is interesting, because it is similar to that which would be offered by many small industries today. They claimed that they were honest tradesmen and should be free to carry out their trade anywhere in the city, adapting their premises to suit the work. They rejected the complaint of nuisance on the basis that the forge they used had long been on the site and the rooms affected by smoke had been built more recently.

Despite the fact that blacksmiths used small quantities of coal, there was considerable reaction against the environmental nuisance they caused. Much of this derived from the noise, dirt and long hours worked.

There is much uncertainty about the success of early attempts to control air pollution in London. The outright ban that was placed on the use of sea-coal by local government was virtually the only effective response. It is possible that they may have encouraged the construction of efficient or tall chimneys. According to a case from Assize Nuisance, the plaintiffs argued that the chimney of the armourers was not as high as good practice required. High chimneys not only carry the pollutants high above our heads but they can also take advantage of the stronger winds aloft. Under stagnant conditions stable layers of air, known as temperature inversions, can trap pollution near ground level. A tall chimney stack can sometimes penetrate through the stable layer of air, but with medieval chimneys the main consideration would have been to ensure that the smoke was removed from the interiors and emitted at sufficient height to clear the neighbouring houses.

A number of other approaches to air pollution control were explored in medieval England. One idea was to place limits on the use of coal. Restriction on the times when furnaces could be used was suggested by one group of London blacksmiths in the 13th century. In late medieval Beverley it seems that a zoning ordinance was set up to ensure that brick kilns were kept at some distance from the town because of the damage caused to fruit trees. It is more than likely that the legislation of the late 13th and early 14th century had little effect. The proclamations of 1307 may have been partially successful because they were specifically promulgated to control lime kilns burning sea-coal. However, it cannot have been so successful against the use of coal in furnaces, because it is apparent that, a few years later, sea-coal was being used for forging.

Even if we can accept the notion that for a short time there was some control on the use of coal in lime burning in the very early part of the 14th century, these controls cannot have been long lived. In 1329 there is evidence that lime was being burnt with coal again. From this point until the mid-14th century there appears to be a gap in the records of complaints about pollution in London. Despite the gap we cannot conclude that air pollution was no longer a problem. However, circumstances in London may have changed slightly. Wood for fuel may have been more plentiful or perhaps the citizens grew accustomed to the smell of coal smoke, even that associated with lime burning. Until Elizabethan times lime burning remained one of the major uses of sea-coal, and Shakespeare complained of the reek from lime kilns (Brimblecombe, 1987a).

3 Smoke inspection

Industrial smoke was an enormous problem in the industrializing cities of 19th century Britain. Despite a long interest in sanitary reform, air pollution improved only slowly, perhaps because of lax administration, poor abatement technology or limited training for stokers and Smoke Inspectors. Training of Sanitary Inspectors began after the Public Health Act 1875, but it was not until 1912 that formalized training was available for Smoke Inspectors. Such a delay probably limited the rate and scale of emission reduction. The inspectors stressed the importance of good stoking practice and the advantages of mechanical stokers, which probably lowered the emission of industrial smoke in the early 20th century (Brimblecombe, 2003a).

The Sanitary Inspectors were responsible for the day to day administration of sanitary law, but a range of more specific skills was required to deal with smoke. Thus a distinct element of sanitary administration, the Smoke Inspectorate, began to emerge around the end of the 19th century.

The earliest attempts to regulate pollution focused on individual industries (such as tanning or brewing) rather than types of combustion process. However, the industrial revolution in the late 18th century drew attention to manufacturers with smoky steam engines. Manchester, especially, saw a particularly early industrial growth that triggered great concern about the impact of smoke from steam engines powering the new factories. The authorities in Manchester soon realized that available medieval nuisance laws were inadequate to control the smoke of an industrializing city (Bowler and Brimblecombe, 2000a). In 1792, Manchester was able to use an Act (32 Geo III) to regulate the streets and passages of the town to create a new body: the police commissioners. The commissioners explored the smoke problem through investigative committees and although they demanded that manufacturers in the town ‘consume their own smoke’, there was little improvement. In 1819, an Act specifically addressed nuisances from engines but, although treated with initial enthusiasm, it was unsuccessful (Brimblecombe, 2003a).

The inspectors directed their attention to reducing the smoke from individual sources. Inspectors also learnt much about methods available for reducing smoke with an emphasis on stoking, most particularly the advantages of mechanical stoking. At the same time they took an interest in gas and electricity as cleaner sources of power. The inspectors contributed to reductions in industrial soot emissions. The office of Sanitary Inspector has evolved into that of Environmental Health (Brimblecombe, 2003b). However, smoke is simply one of a range of pollutants that must be considered by those attempting to improve air quality (Brimblecombe, 2003a).

4 Smoke and the London fog

It seemed in the period that followed the passage of the Smoke Nuisance Abatement Acts that it would be only a matter of time before London’s air pollution problems were solved. It was thought that, given sufficient vigilance on the part of the public and the authorities, the legislation should work. In many cities, however, complications with local legislation meant that the laws on smoke abatement were often ignored. For instance, in London the magistrates became reluctant to impose fines that were large enough to discourage pollution of the air. So by the 1880s it appeared that the enthusiasm for smoke abatement had lost some of its early drive.

As there was no air pollution monitoring network within London in the late 19th century, nobody really knew how much pollution was in the city’s air. A few samples of rainfall had been taken and analysed by R.A. Smith, the first Alkali Inspector, in 1869 and 1870, but these isolated measurements could not indicate improvements or other long-term changes. On the one hand, the factory owners could point to the huge chimneys and show that there had been some decline in the emission of black smoke; on the other hand, the frequency and thickness of London fog had increased. Furthermore, gloom became more frequent in the city.

There had always been fogs along the Thames, but at this time people began to sense that the fogs were related to air pollution. The fogs of the 19th century were thicker, more

frequent and of a different colour from those of the past. It is difficult to know how long ago all these changes had started. Some of the earliest records of London fog come from the notebooks of the famous astronomer Thomas Harriot (1560–1621). He was using one of the earliest telescopes in England to observe the face of the Sun. To cut down the brightness of the solar disc, he had to observe it through mist or cloud, so his records contain numerous references to the clarity of the atmosphere in the first decade of the 17th century. Fogs were by no means infrequent but they were probably of quite natural origin. However, by the end of the 17th century it is no longer as easy to be so sure that the city was not partly responsible for some of the worst fogs. John Gadbury, the nautical astronomer, noted some of the very thick persistent London fogs as 'Great Stinking Fogs' in his weather diary of the late 17th century. H.R. Bentham, a German visitor of the 1680s, also remarked on London's fogginess in his travelogue. The high frequency of references to fog in London in the late 17th century suggests that it was rather foggier than was to be expected. This may have been the result of a more stable pattern of atmospheric circulation, which would have inhibited the dispersal of fog during this part of the Little Ice Age.

It became evident to a number of people interested in smoke abatement in Victorian England that long-term records of the fogginess of London would be very useful in determining changes in the quality of the city's air. On the basis of a 200-year dataset, Mossman came to the conclusion that there had been a startling increase in the fog frequency over that period. Brodie could also detect an increase even over the relatively brief period of 1870–1890.

In the early 1880s, the most active smoke abatement group in London was the Fog and Smoke Committee. From the start it seemed that, although some tightening of the existing regulations might be possible with regard to the emissions from factories, there would be no way of extending these to cover domestic smoke. The Committee wisely pursued the problem of domestic emissions not through legislation but by setting examples. Some abatement enthusiasts maintained that the problem arose simply because servants didn't know how to make a good fire. Perhaps this was the case with anthracitic coals, and there was a suggestion that Welsh girls be sent down to the city to show the Londoners how to make a decent fire with the harder coal.

London had gained its reputation as a foggy city from German travellers of the late 17th century. At first the visitors were disappointed when a fog restricted their view of the capital but, by the 19th century, many were even disappointed if they were not confronted by 'London's Particular'. In October 1888, the poet James Russel Lowell, who was US minister to England, wrote as follows:

> 'We are in the beginning of our foggy season, and today are having a yellow fog, and that always enlivens me, it has such a knack of transfiguring things. It flatters one's self-esteem, too, in a recondite way, promoting one for the moment to that exclusive class which can afford to wrap itself in a golden seclusion. It is very picturesque also. Even the cabs are rimmed with a halo, and people across the way have all that possibility of suggestion which piques the fancy so in the figures of fading frescoes. Even the grey, even the black fogs make a new and unexplored world not unpleasing to one who is getting palled with familiar landscapes.'

The foggy season began in the late autumn and continued until winter had passed, but November was popularly considered to be the worst month. Certainly, the novelists found the month to be cold and foggy, and detective stories find it an essential

background. November was renowned not only for its fogs: Frederick Marryat, author of *Children of the New Forest*, wrote that November was also the month of misanthropy and suicides. It has been said that there was a French proverb, which claimed that:

> 'In October the Englishmen shoot pheasant
>
> In November he shoots himself'.

A whimsical poem by Thomas Hood plays on the problems that beset the month:

> 'No sun, no moon ...
>
> No leaves, no birds
>
> NOVEMBER'

It is probable that the November fogs had particular impacts because they were both thick and persistent. If only the days of very thick fog are considered then even in the records from the 20th century, November is found to have the highest frequency. Gloom covered the city in the winter months. The psychological and meteorological glooms were no doubt interconnected as there are endless descriptions of the dismal conditions that prevailed in the early part of the London winter. It was so dark that houses and shops had to be lit during the day.

This meant that new terms such as 'day darkness' and 'high fog' began to appear in the London vocabulary. The latter term, particularly, was used to describe the occurrence of dark periods in the day, when no fog was apparent at ground level. At such times the Sun was sometimes totally obscured and, although it was very dark, it was still possible to see the lights of buildings some miles away.

On 16 January 1955, a high-level smoke layer caused a period of day darkness. This particular event occurred when extensive instrumentation was available. It is probably a reasonable model for earlier occurrences, so it is worth examining in some detail. The weather pattern was characterized by a deep depression with rather weak pressure gradients near the centre (giving light winds) and very active fronts, which gave rise to dense clouds. Here was fog and a temperature inversion in the lower layers of the atmosphere. In the morning light, winds carried the smoke from London to the north-west. The smoke was unable to disperse because the inversion prevented vertical mixing. Estimates suggest that the original smoke layer was some 175 m thick. The smoke reached the Chilterns just at the time when a cold front crossed them. It is possible that the smoke-laden air was lifted vertically in the vigorous convergence at the front. This would have stacked the smoky air in a vertical column more than a kilometre thick. Reports from aircraft suggest that the cloud layer was continuous and deep, stretching from 400–4000 m altitude. About midday, the smoke parcel began to pile up over the Chilterns. Shortly afterwards the wind reversed direction and gradually increased in strength. This carried the air, with the extremely dense pillar of smoke and cloud above it, back across London. The light intensity on a sunny January day in the capital would have been about 36 kilolux, while illumination on a heavily overcast January day would fall about 7 kilolux. On the examined day at about 13.15 hours, the light level dropped from 7 kilolux to less than 0.03 kilolux. Almost total darkness followed for six minutes. People who experienced this phenomenon said it seemed as if the world was coming to an end.

Psychological implications of fogs have already been mentioned. Also, not doubt, it affected tourism but then maybe some people actually wanted to see the fogs. Additional

costs arose from gas lighting and transportation because of frequent accidents, and extra cleaning was required because of the sooty deposits left afterwards.

The effect of fog on transport had been a problem from the earliest times, and was even noted in records of 17th century London life. Anthony Woods records a great mist in London on 11 November 1667, when 'horses ran against each other, carts against carts, coaches against coaches, etc.' Although thick fogs may have hampered travellers of that time they brought complete chaos to the transport system of Victorian London. Between 8 and 14 December 1873, the fog was so thick that 15 people were said to have drowned in the Northside docks.

There was increased mortality from disease during times of fog. Of course, there is always an increase in mortality during the winter, but it was no longer possible to dismiss some of the increases as random fluctuations. In the week of fog in 1873 it appears that there were 700 more deaths than normally expected in London at that time of year. Such episodes did not end with the Victorian era, as there have been a handful of bad fogs in the 20th century. The worst of these fogs was The Great Smog of 1952 (Table 1).

Table 1 Major London smogs (source: Brimblecombe, 1987a).

Year	Month	Duration (days)	Excess deaths	Maximum daily SO_2 concentration/$\mu g\ m^{-3}$	Maximum daily smoke concentration/$\mu g\ m^{-3}$
1873	December	3	270–1000		*a*
1880	January	4	700–1100		
1882	February				
1891	December				*b*
1892	December	3	≈ 1000		
1948	November	6	≈ 300		
1952	December	5	4000	3700	4460
1956	January		480	2800	1700
1957	December		300–800	2800	3000
1962	December	4	340–700	4100	1900
1975	December	3	*c*		500–600
1982	November			560	

[a] Smoke levels in the early fogs were 800 $\mu g\ m^{-3}$ or greater.

[b] The soot deposit during this fog was 9.4 $g\ m^{-2}$.

[c] Not statistically significant.

Naturally, animals were also affected by the fogs. In the fog of 1873 many of the cattle that were in London for exhibition at the Great Show at Islington are said to have died of suffocation.

5 The effect of pollutants

The air pollution in London continued to be severe in the early 20th century despite the slight decline in the frequency of London fog. Long exposure to polluted atmospheres brought new problems. In the railway station at Charing Cross a girder collapsed. Analysis showed that it contained nearly 9% ferrous sulfate, which had been produced

from continued exposure to sulfurous coal smoke. Investigations in other stations showed that the problem was not unique to Charing Cross.

The stonework of London's buildings decayed more rapidly than ever at the turn of the 19th century. Such damage affected London's great architectural heritage. The enormous growth of the Victorian cities and their parallel pollution problems confronted architects with great difficulties. Environmental pressures included denial of light, overcrowding, awkward sites, noise, accessibility and visibility of buildings as well as air pollution. Corrosive pollutants were damaging to all buildings but especially the minutely detailed Gothic architecture popular in Victorian Britain. Dense smoke made cities dark, coated the windows and penetrated inside buildings, damaging the contents. Architects began to alter the design of their buildings in recognition of the smoke problem, which may ultimately have caused the decline of neo-gothic in the late Victorian period (Bowler and Brimblecombe, 2000b).

Corrosion of buildings converted their limestone ($CaCO_3$) into gypsum ($CaSO_4$). Two properties of gypsum (its molecular volume is considerably greater than that of limestone and it is much more soluble in water than calcium carbonate) encourage rapid deterioration of stonework. Corrosion of metals is enhanced by the sulfuric acid that is produced by oxidation of SO_2. Because medieval glass contained a large amount of calcium, it was more susceptible to attack by both water and SO_2. Plants were also heavily stressed by pollutants. At higher concentrations of SO_2 the cells of the mesophyll in leaves collapse and the leaves take on a dull green watersoaked look. On drying, these damaged areas appear whitish.

Doctors directed that asthmatic and consumptive patients be removed to the country so that they might avoid the harmful effects of the city air. After all, doctors in Imperial Rome had given the same advice to those with weak lungs and money in ancient times.

Fashions also continued to be affected. Dull-coloured outdoor paints remained the most popular. Indoors, dark-coloured wallpapers were in vogue and the cleaning of curtains was a continuing problem. The decline in popularity of silver plate through the early part of this century is blamed on the tarnishing effect of the urban atmosphere but then it may merely have been that good servants to clean it were becoming so hard to find.

6 The Great Smog and after

At the turn of the 19th century, smoke control in London was embodied in the Public Health (London) Act of 1891, which had arisen from the Public Health Act of 1875. The Act did not apply to private chimneys, but other fires and furnaces were required, as far as practicable, to consume all smoke. This sounds very reasonable but the difficulty was that the Act stated that 'any chimney sending forth black smoke might be deemed a nuisance'. How does one define 'black smoke'? This deficiency has meant a problem for a long time in applying the Act.

Some important dates in the struggle against smoke:

- 1926: the passage of the Public Health (Smoke Abatement) bill;
- 1932: 155 authorities had framed by-laws concerning the abatement of smoke but for the main they related only to black smoke and the duration of its emission;

- 1946: the City of London (Various Powers) Act and the Manchester Corporation Act allowed these cities to create smokeless zones.

The advances in environmental legislation, as in smoke control technology were more rapid in the post-war years but all these changes paled before those catalysed by The Great Smog of 1952.

The mixture of smoke and fog that settled in over London had been common in Victorian times. In 1905 Des Voeux proposed that this mixture be termed 'smog'. Through the first half of the 20th century it appeared that the famous London smogs had become rarer and the increased death rates they brought were remembered only in medical histories.

It seemed that Robert Barr's prediction of 'The Doom of London' would forever remain mere fiction but that proved not entirely so, for London was to have its Great Smog. Reminiscent of Barr's prophesy, the weather in the week that preceded the smog of 1952 was relatively good. Each day had its gentle breezes and glimpses of sunshine but, by Thursday 4 December, the conditions began to deteriorate. The winds became slacker, the air damper and the skies grey. A slow-moving anticyclone came to a halt over the city of London. By Thursday evening it was evident that London would be very foggy. When Friday came, the scene was positively Dickensian. There was

> 'fog everywhere, fog up the river where it flows among green aits and meadows – fog down the river, where it rolls defiled among the tiers of shipping and the waterside pollutions of a great (and dirty) city. Fog on the Essex marshes, fog on the Kentish heights. Fog creeping into the cabooses of collier-brigs; fog lying out on the yards, and hovering in the rigging of great ships; fog drooping on the gun-whales of barges and small boats. Fog in the eyes and throats of ancient Greenwich pensioners, wheezing by the firesides of their wards; fog in the stem and bowl of the afternoon pipe of the wrathful skipper, down in his close cabin; fog cruelly pinching the toes and fingers of his shivering little prentice boy on the deck.'

The fog was thicker on that Friday morning than many people could ever remember. Through the day it steadily grew even thicker. In the afternoon people were already experiencing discomfort, and noticing the choking smell in the air. Those who walked about in the fog found their skin and clothing quite filthy after a short time. By Friday night the treatment of respiratory cases was running at twice its normal level and the anticyclone had stalled completely. A million chimneys poured smoke out into the foggy stagnant air.

On Saturday the fog was still there. Gradually, with visibility near zero, the transport system began to grind to a halt. People continued to suffer and some died. On Sunday the fog continued and so did the deaths. The emergency services were no longer able to respond in any effective way. It is doubtful whether many people perceived the nature of the calamity that had befallen them. The Victorians would have known that such fogs were killers but they had become uncommon in the 20th century. When Monday morning came conditions seemed slightly better and the transport services gradually came to life, although delays abounded. On Tuesday the Great Smog was over.

It was difficult to describe quite what had happened. The air pollution monitoring equipment operating in London was still fairly primitive at that time; however, the smog seem to give a coherent picture of the incident. The changes in SO_2 and smog concentrations were compared with mortality. The highest daily mean recorded smoke

concentration (5 December) was 4460 $\mu g\,m^{-3}$ and that of SO_2 3700 $\mu g\,m^{-3}$, but in some shorter periods these values might have been, of course, much higher. The four hours of densest smoke at the National Gallery could have been as high as 14 000 $\mu g\,m^{-3}$: a phenomenally high level of pollution.

According to hospitals' reports the number of cases of respiratory disease quadrupled. During the 5 days of fog the number of deaths was 4703, compared with 1852 in the same period of the previous year. Symptoms that developed during the incident were typically a cough with relatively little sputum, nasal discharge, sore throat and sudden attacks of vomiting. The most affected were those with a previous history of chronic bronchitis, asthma, bronchiectasis or one of the forms of pulmonary fibrosis. The illnesses had a sudden onset and many of the most severe cases began on the third or fourth day of the fog. Men were attacked with greater frequency than women and the sick were generally over 45 years of age. Death rates showed a sharp fall at the end of the episode (Brimblecombe, 2002).

The government's bill was debated in late 1955. After the general election, on the basis of the report of the Beaver Committee, the new government enacted the Clean Air Act of 5 July 1956. Perhaps the most radical element of this Act was that, for the first time, legislation attempted to control domestic sources of pollution as well as those of industry. The specific actions were detailed in memoranda on chimney heights, smoke control areas and industrial premises. The law was still restricted to smoke but prohibited dark smoke. Even the smog of 1952 would not have been a successful ally, had it not been for the changing social conditions. If servants had still been available to clean out dirty grates and stoves, who would have pressed for change? Had electricity or gas not been reasonably priced, who would have pressed for colder homes by banning the fuel that would heat them cheaply and efficiently? The Clean Air Acts enabled local government to set up smoke control areas (often called smokeless zones). By the time of local government reorganization in 1974, all but 14 local authorities had taken some steps towards implementing the Act. Factories built high stacks and applied high quality smoke-arresting equipment, which are very effective. Domestic sources now account for more than 90% of the smoke in the air, but even so, these domestic emissions have declined considerably compared with those in 1970s (Brimblecombe, 1987a).

The improvement in London's air has been dramatic, to say the very least. The picture is an encouraging one, suggesting that, given sufficient will, society can be both more affluent and less polluted. London, once one of the black areas on the Beaver map, the foggiest city of literature and the dirtiest metropolis of Europe, may no longer deserve such extreme appellations. Although London still has the occasional bad fog, many small towns, considered quite clean, are now sometimes smokier than the capital (Brimblecombe, 1987a).

7 The London fog in literature and the fine arts

Fog seems to be a prerequisite for detective stories set in London, and no period novel can any longer be written without reference to it. In Conan Doyle's *The Sign of Four*, the September evening proves to be a foggy one when Sherlock Holmes, Watson and Miss Morstan travel out to Upper Norwood, but by the time they pass Norwood the fog is far behind.

In the scientific literature there seems to be no satisfactory explanation for the colour of the fog. The earliest descriptions in diaries are vague but, as time went on, yellow fogs became more frequently noted. Although at the start of the 19th century Byron said that London had ‘a dun coloured cupola’, it wasn’t until the 1840s that the thick yellow London fog really arrived. The source of the colour is difficult to ascertain but a number of possibilities spring to mind. It is conceivable that fine smoke particles in the atmosphere could absorb the blue wavelengths from the sunlight above the fog in such a way that fog at ground level was illuminated by a yellow light. It is possible that the fog at night was yellowed by the light of the gas lamps and the glare from shop windows.

It is also possible that the colour might have been the result of compounds present in fog droplets. In the Sherlock Holmes story, *The Adventure of the Bruce-Partington Plans*, we hear of a fog settling in over London in the November of 1895. On the fourth day of the fog Watson, through his intermediary and literary executor, Conan Doyle, wrote that: ‘we saw the greasy, heavy brown swirl still drifting past us and condensing into oily drops upon the window panes’. This suggests that the droplets may have actually contained coloured substances.

The most pertinent example of a story that brings home the link between air pollution and the destruction of London is Barr’s *The Doom of London.* The book, written after a bad series of fogs, was a chilling and prophetic vision. With Barr’s story the link between pollution and the destruction of the city is more direct. Almost the entire population of London dies of asphyxiation in a fog that envelops the metropolis.

This vision also found expression in a number of works of art of the 19th century. Monet visited the capital in the early part of his career and did not seem to be bothered by the fog at all. His painting *The Thames below Westminster*, which hangs in the National Gallery, is a good example. Monet deliberately chose to visit London in the winter in order to paint his Thames series. Other Impressionists, such as Pisarro, included the word ‘fog’ in the titles of their paintings. Fogs and air pollution did not stifle artistic development. The Chinese artist Chiang Yee, who was active in London of the 1930s, wrote of the fog in his book *The Silent Traveller in London* and found the fogs an inspiration and an aid to creating perspective in his oriental style (Brimblecombe, 1987a).

8 Vision of a foggy apocalypse

Environmental degradation within cities may have seemed so severe to some that cities had little future. In short, they would destroy themselves, and their polluted atmospheres were seen as an agent of destruction. The Victorians did not find it difficult to accept the idea of a foggy apocalypse for London but it never really happened with the imagined finality, even in the Great Smog of 1952.

In John of Patmos’ *Book of Revelation*, subsequent destructions occur in terms of floods, earthquakes and volcanoes. Artistic expressions in the book, representing the impending apocalypse, had an increasing emphasis on urban disaster. Negative visions of the city also became embedded in philosophy. Nietzsche wrote: ‘O Zarathustra, spit on this city of shopkeepers and turn back! Here all blood flows putrid and lukewarm and spumy through all the veins ... where everything infirm, infamous, lustful, dusky overmusty, pussy and plotting putrifies together ...’ (Brimblecombe, 2004).

However, learned review essays and great novels are probably not the right place to look for popular perceptions. The Victorian age was one of increasing literacy, with the detective story, mystery writing and science fiction gaining wide readership. Detective fiction (e.g. Sherlock Holmes stories) grew among London fogs that obscured criminal deeds. Mysteries such as *Dr. Jeckyll and Mr. Hyde* and Bram Stoker's *Drakula* (1897) thrived in urban chaos. Perhaps more significant are the range of clearly apocalyptic books, such as Richard Jefferies' *After London* or *Wild England* (1885) as well as H.G. Wells' *Time Machine* (1894) and *The War of the Worlds* (1898), furthermore A.C. Doyle's *The Poison Belt* (1913).

The notion of apocalypse remains an enduring theme within environmental debate. It no doubt sharpens focus on many issues, e.g. the greenhouse effect or the nuclear winter. If apocalyptic viewpoints imply that the environment is beyond repair or control, it could suggest that we are free from responsibility for the state of our world; hardly something the Victorians would wish as an interpretation of their legacy (Brimblecombe, 2004).

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